# Electrostatics Kit

## (Order Code ESK-CRG)

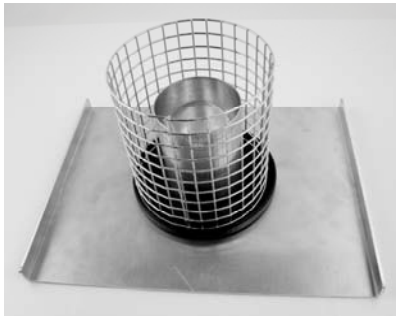
The Electrostatics Kit is an accessory for the Vernier Charge Sensor. This kit allows students to perform a range of experiments in electrostatics. Experiments include

- Using Faraday's Ice Pail
- Production of charge by friction
- Transfer of charge by contact
- Charging by Induction
- Quantitative and qualitative measurement of charge

## What is Included with the Electrostatics Kit?

| | |
|---|---|
| Faraday Pail (aluminum can) | Ground Plane (flat metal sheet) |
| Cage (metal wire cage) | Grounding Wrist Strap |
| (2) Grounding Wires | Square of wool (fabric) |
| (2) Charge Separators | Square of vinyl (plastic pad) |
| Proof Plane | PVC rod (gray) |
| Cotton cloth | Nylon rod (white) |

## A Closer Look at the Components



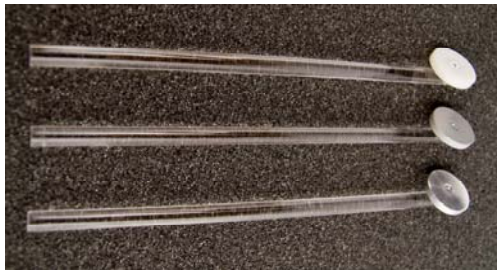
*Faraday Pail, Cage, and Ground Plane*

The key part to this kit is the Faraday Pail, Cage, and Ground Plane. The Faraday Pail is used in the measurement of electrostatic charge on objects. Charged objects placed inside the Pail induce equal magnitude but opposite charge on the inside of the can. This in turn produces a charge on the outside of the can which has the same sign as the object in the can. A Charge Sensor attached to the Pail allows you to determine the magnitude and sign of the charge on the object.

The Ground Plane is the sheet of metal that the equipment sits on. The Ground Plane is used to ground objects such as the Faraday Pail, the Cage or the experimenter.

The Cage is the cylindrical metal mesh, and it sits on a plastic plate. During experiments you will want to use a Grounding Wire to ground the Cage to the Ground Plane.

The Faraday Pail sits inside the Cage but on the plastic plate. The charge on an object can be measured when the object is placed inside the Pail, assuming that the Charge Sensor is connected to the pail. You can also measure charge by transferring it to the Pail through contact.



*Charger Separators and Proof Plane*

Another set of key components are the Charge Separators and Proof Plane. These three objects have acrylic handles. The Proof Plane has a metal conducting disk that is used to test the charge on an object. The two Charge Separators are different materials. The gray material is PVC and the white one is nylon. When rubbed together, the gray PVC develops a negative charge while the white Nylon develops a positive charge. A small cotton cloth is included with this kit. The cloth is used to remove excess charge on the Charge Separators. Dampen the cloth with water and touch all the surfaces of the Charge Separators to the cloth.

*Traditional Charger Separators*

A set of traditional Charge Separators is also included. One set consists of a white nylon rod and a vinyl pad. When the nylon and vinyl are rubbed together, the nylon rod becomes positive and the vinyl becomes negative. The other set is a gray PVC rod and wool cloth. When the PVC and wool are rubbed together, the PVC develops a negative charge while the wool develops a positive charge.

## Performing Experiments with the Faraday Pail and the Vernier Charge Sensor

The key part to this kit is the Faraday Pail and Cage. When the Charge Sensor is attached to the Pail, the Pail can be used to qualitatively and quantitatively measure charge on objects. Follow these instructions to set up the equipment.

1. Place the plastic disk that holds the Faraday Pail and cage on the Ground Plane.
2. Place the Faraday Pail and the Cage on the disc.
3. Connect the black lead from the Charge Sensor to the Ground Plane.
4. Connect the red lead from the Charge Sensor to the Faraday Pail.
5. Connect the Charge Sensor to an interface, such as a LabQuest or LabPro.
6. Connect a Grounding Wire between the Cage and the Ground Plane.
7. Ground the system and zero the sensor by pressing and holding the Reset button on the sensor.
8. Now insert an object into the center of the Faraday Pail. While the object is in the Pail, the Charge Sensor will display the charge.

Quantitative measurement of electrostatic charge can be challenging. Many factors enter into the buildup of electrostatic charge and your ability to measure the charge. The Charge Sensor is a very sensitive device and it can detect charge on objects where you may not expect to see it, e.g., your body. Your success is also a function of atmospheric humidity. Electrostatic studies are difficult in humid environments because objects discharge quickly through multiple paths.

The Charge Sensor contains a range switch. You need to select a range that is appropriate for the experiment and environmental conditions. For example if you are measuring a small electrostatic charge, the smallest range setting on the sensor may be appropriate; however, if the sensor is reading its maximum value, you may want to switch to a higher range.

Note: As you collect data for different situations, you will need to zero the Charge Sensor since it is extremely easy to pick up stray charges. If the sensor reading appears to drift, simply press the Reset button on the sensor between data-collection runs. A good practice is to zero the Charge Sensor before each trial.

## Sample Experiments

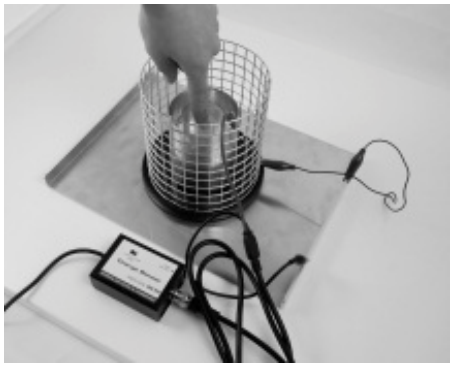
There are a variety of experiments that can be performed with this kit and a Charge Sensor. Below you will find three detailed examples. You might want to try them out to learn more about the equipment. Those examples are followed with brief descriptions of other experiments.



### Learning to use Faraday Pail and the Vernier Charge Sensor – How much electrical charge can your body carry?

The following experiment is a great introduction to this kit and the Vernier Charge Sensor. The activity demonstrates the sensitivity of the equipment. In the activity the user explores the charge that the body can carry and how to discharge the sensor and the body.

1. Attach the Charge Sensor black lead to the Ground Plane.
2. Attach the Charge Sensor red lead to the Faraday Pail.
3. Connect a Grounding Wire between the Cage and the Ground Plane.
4. Ground the system and discharge the sensor by pressing and holding the Reset button on the sensor.
5. Do not attach the grounding strap to your arm, because the purpose of this experiment is to show how your body can become charged.
6. Scuff your shoes on the floor. Insert a finger into the Faraday Pail without touching the Pail. What does it read? [The answers will vary but should be different from zero.]
7. Remove your finger. What does it read? [Close to zero.]
8. Explain your findings. [Scuffing the shoes built up a charge on the body. The Faraday Pail and Charge Sensor detected the charge. When the finger is in the Pail, the sensor detects a charge. When the finger is removed, it detects no charge. The magnitude and sign of the charge will depend upon the composition of the flooring and shoes.]
9. Touch the Ground Plane with your finger.
10. Insert a finger into the Faraday Pail without touching the Pail. What does it read? [Should be close to zero]
11. Remove your finger. What does it read? [Should be close to zero]
12. Explain your observations. [Touching the Ground Plane removes the charge from the body. The charge on the body should be zero. The Charge Sensor reading should be close to zero regardless of whether the finger is in the Pail or not.]
13. If possible, scuff your shoes on a different type of flooring. Insert a finger into Pail. What does it read? [Answers will vary but should not be zero.]
14. Remove your finger. What does it read? [Close to zero]
15. Explain your findings. [Again a charge should be detected on the body. The magnitude and sign of the charge will depend upon the composition of the flooring and shoes.]
16. Insert your finger into the Pail. Touch the Pail and remove your finger. What does the sensor read? Explain findings. [Touching the Pail leaves a charge.]



17. Ground the Pail and zero the sensor by pressing and holding the Reset button on the sensor.
18. Scuff your shoes on the floor. Insert a finger into the Pail without touching. What does it read? [Should be a non-zero number.] Remove your finger. Now move your finger toward the wire Cage. What does the sensor read? [It should remain unchanged from before.] What does that say about the Cage? [The Cage shields the Faraday Pail from external charges.]

### Observe the separation of charge using common materials

Rub dissimilar materials together to generate a charge on each. Use the Faraday Pail and Charge Sensor to measure the sign of the charge on each. The materials investigated are wool fabric, vinyl pad, nylon rod (white) and PVC rod (gray).

1. Attach the Charge Sensor black lead to the Ground Plane.
2. Attach the Charge Sensor red lead to the Faraday Pail.
3. Connect a Grounding Wire between the Cage and the Ground Plane.
4. Attach the grounding strap to your wrist.
5. Ground the system and discharge the sensor by pressing and holding the Reset button on the sensor.

6. Fold the vinyl in half, in quarters, and then in eighths. The peak that forms from these folds will be an object for which you will measure charge. Rub the white nylon rod back and forth along the peak of this vinyl. Insert the rod into the Pail without touching the Pail. What is the sign of the charge? [Positive]
7. Insert the vinyl peak into the Pail without touching the Pail. What is the sign of the charge? [Negative]
8. Fold the wool in half, in quarters, and then in eighths. Rub the gray PVC rod back and forth along the peak of the wool. Insert the rod into the Pail without touching the Pail. What is the sign of the charge? [Negative]
9. Insert the wool peak into the Pail without touching the Pail. What is the sign of the charge? [Positive]

### Explore charging by induction using the Charge Separators

1. Attach the Charge Sensor black lead to the Ground Plane.
2. Attach the Charge Sensor red lead to the Faraday Pail.
3. Connect a Grounding Wire between the Cage and the Ground Plane.
4. Attach the grounding strap to your wrist.
5. Ground the system and discharge the sensor by pressing and holding the Reset button on the sensor.



6. Rub the Charge Separators together.
7. Place the white Charge Separator in the Pail being careful to not touch the side of the Pail. What is the sign and magnitude of the reading? [Should be positive. Magnitude will vary.]

8. While the white Charge Separator is in the Pail, ground the Pail by touching it with your finger. What does the sensor read? [Should be close to zero.]
9. Remove your finger. What does the sensor read? [Should be close to zero.]
10. Remove the Charge Separator. What is the sign and magnitude of the charge as shown by the sensor? [Should be negative and have a magnitude similar to that seen in #7.]
11. Move the Charge Separator back into the Cage; what is the sign of the charge? What is the magnitude of the charge? [Should be close to zero.]
12. Explain your results. [The charge on the Charge Separator is positive. When it is inside the Pail, the sensor shows a positive charge. When the Pail is grounded, negative charge from the grounding plane is attracted to the Pail leaving the Pail negative. These positive and negative charges cancel and the sensor reads zero. When the ground is removed, a negative charge is left on the Pail, but it is being canceled by the positive charge on the Charge Separator; therefore the sensor still reads zero. When the Charge Separator is removed, the negative charge on the can is no longer cancelled by the positive charge on the Charge Separator, and the sensor reads negative. When the Charge Separator is placed back into the Pail, the charges now cancel each other and the sensor again reads zero.]
13. Repeat with the gray Charge Separator and explain your results. [The charge on the Charge Separator is negative. When it is inside the Pail, the sensor shows a negative charge. When Pail is grounded, negative charge on the Pail is repelled to the grounding plane leaving the Pail positive. These positive and negative charges cancel and the sensor reads zero. When the ground is removed, a positive charge is left on the Pail, but it is being canceled by the negative charge on the Charge Separator; therefore the sensor still reads zero. When the Charge Separator is removed, the positive charge on the Pail is no longer cancelled by the negative charge on the Charge Separator and the sensor reads positive. When the Charge Separator is placed back into the Pail, the charges now cancel each other and the sensor again reads zero.]

## Other experiments

Here are some other ideas for experiments.

### What does the wrist strap do?

Use the Faraday Pail and Charge Sensor to understand the function of the grounding wrist strap. Scuff your shoes on the floor and use the Faraday Pail to measure the charge on your body. Next attach the grounding strap to the Ground Plane and put the strap on your wrist. Scuff your feet on the floor and measure the charge. It should be close to zero with the wrist strap attached.

### Explore charge separation using the Charge Separators

Use the Charge Sensor, Faraday Pail and Charge Separators in this kit to measure the sign and magnitude of charge. Since the Charge Separators are small, you can rub them together and then place either or both of them in the Faraday Pail. When inserted individually, you can observe that equal amounts of charge with different sign appear on the different materials. When they are simultaneously inserted into the Pail, the charge is close to zero indicating the cancellation of equal but opposite charges.

For more information on charge separation, search for "triboelectric effect" online.

### Explore charge separation using invisible tape

Use the Charge Sensor and Faraday Pail to observe the separation of charge when two strips of invisible tape are pulled apart. On two 3 inch pieces of tape, make a tab by folding over the top of each. Stick the combination to the table top. Pull the combination off the table and then pull the top strip off the bottom strip. Individually place each strip into the Faraday Pail to measure the charge. Simultaneously place them in the Pail to measure the charge.

### Explore charging by contact using the Charge Separators

Use the Charge Sensor, Faraday Pail and Charge Separators in this kit to measure the charge transferred from one object to another. Rub the Charge Separators together.

Place the white Charge Separator in the Pail without touching the Pail. Note the charge. Now touch the white Charge Separator to the metal can and remove the Charge Separator from the can. Again note the charge. Ground the system and discharge the sensor by pressing and holding the Reset button on the sensor. Repeat these steps with the gray Charge Separator.

## References

Many of the experiments described here are based on suggestions from Robert Morse, Ph.D. We recommended reading the following work by Dr. Morse.

*Electrostatics with Computer-Interfaced Charge Sensors*, The Physics Teacher, November 2006, Volume 44, Issue 8, pp. 498-502

Robert A. Morse, *Teaching About Electrostatics*, AAPT, College Park, MD, 1992



Another excellent resource especially for the invisible tape activity is

Chabay, Ruth, and Sherwood, Bruce, *Matter and Interactions II:Electric and Magnetic Interactions*, John Wiley & Sons, Inc., New York, 2007

## Other Products for Use with this Kit

### Vernier Charge Sensor (CRG-BTA)

The Charge Sensor is used as an electronic electroscope that can make quantitative measurements. Numerical measurements improve many electrostatics experiments such as charging by induction, charging by friction, and charging by contact. The sensor can also be used to measure charge polarity.

### High Voltage Electrostatics Kit (HVEK-CRG)

The High Voltage Electrostatics Kits is an accessory for the Vernier Charge Sensor (order code CRG-BTA). Use it with a Faraday Pail, which is part of this kit, and the Charge Sensor to investigate the charge on a sphere. The current output of the High Voltage Source is extremely low, making it safe for electrostatic studies.

Experiments include

- Investigate the distribution of charge on a sphere
- Transfer of charge on contact between two spheres
- Charging by Induction

The kit includes

- Electrostatic High Voltage Source (output 750, 1500, 3000, 6000 VDC)
- Ground Wire
- Voltage Terminal
- Proof Plane
- Conducting Spheres (2)

## Warranty

Vernier warrants this product to be free from defects in materials and workmanship for a period of five years from the date of shipment to the customer. This warranty does not cover damage to the product caused by abuse or improper use.

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